In [476…
```
%matplotlib notebook
import numpy as np
import sympy as sp
from matplotlib import pyplot as plt
from sympy import MatMul

from matplotlib.animation import FuncAnimation
from mpl_toolkits.mplot3d import Axes3D
import subprocess
from IPython.display import HTML
from IPython import display
from mpmath import *
from scipy import special
```

In [501…
```
r,z,a,K,E,m,phi,x,y=sp.symbols('r,z,a,K,E,m,phi,x,y')
Cart=sp.Matrix([[sp.cos(phi),-sp.sin(phi),0],[sp.sin(phi),sp.cos(phi),0],[0,0,1]])
```

In [502…
```
def K1(m1):
    #return float(abs(ellipk(m1)))
    return special.ellipk(m1, out=None)

def E1(m1):
    #return float(abs(ellipe(m1)))
    return special.ellipe(m1, out=None)
```

In [503…
```
KK=np.vectorize(K1)
EE=np.vectorize(E1)
```

In [504…
```
#Br=a*z/(2*sp.pi*(2*r*a)**(3/2))*(sp.sqrt(2*m)*KK(0)-((2-m)/(2-2*m))*sp.sqrt(2*m)*E
##Bz1= a/(2*sp.pi*(2*r*a)**(3/2))*((m*E*sp.sqrt(2*m)*a**2/(2-2*m))-r*(sp.sqrt(2*m)*
#B=sp.Matrix([Br,0,Bz1])
```

In [505…
```
u0=4*np.pi*10**-7
k=u0/(2*sp.pi)

Br=a*z/((2*r*a)**(3/2))*sp.sqrt(2*m)*(K-((2-m)/(2-2*m))*E)
Bz1= a/((2*r*a)**(3/2))*sp.sqrt(2*m)*(((m*E*a)/(2-2*m))+r*(K-((E*(2-m)/(2-2*m)))))
B=sp.Matrix([-Br,0,Bz1])
```

In [506…
```
B
```

Out[506]:
$$\begin{bmatrix} -\frac{0.353553390593274\sqrt{2}a\sqrt{m}z\left(-\frac{E(2-m)}{2-2m}+K\right)}{(ar)^{1.5}} \\ 0 \\ \frac{0.353553390593274\sqrt{2}a\sqrt{m}\left(\frac{Eam}{2-2m}+r\left(-\frac{E(2-m)}{2-2m}+K\right)\right)}{(ar)^{1.5}} \end{bmatrix}$$

In [507…
```
Bxyz=sp.simplify(Cart*B)
```

In [508…
```
Cart
```

Out[508]:
$$\begin{bmatrix} \cos(\phi) & -\sin(\phi) & 0 \\ \sin(\phi) & \cos(\phi) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

In [509…
```
-Br
```

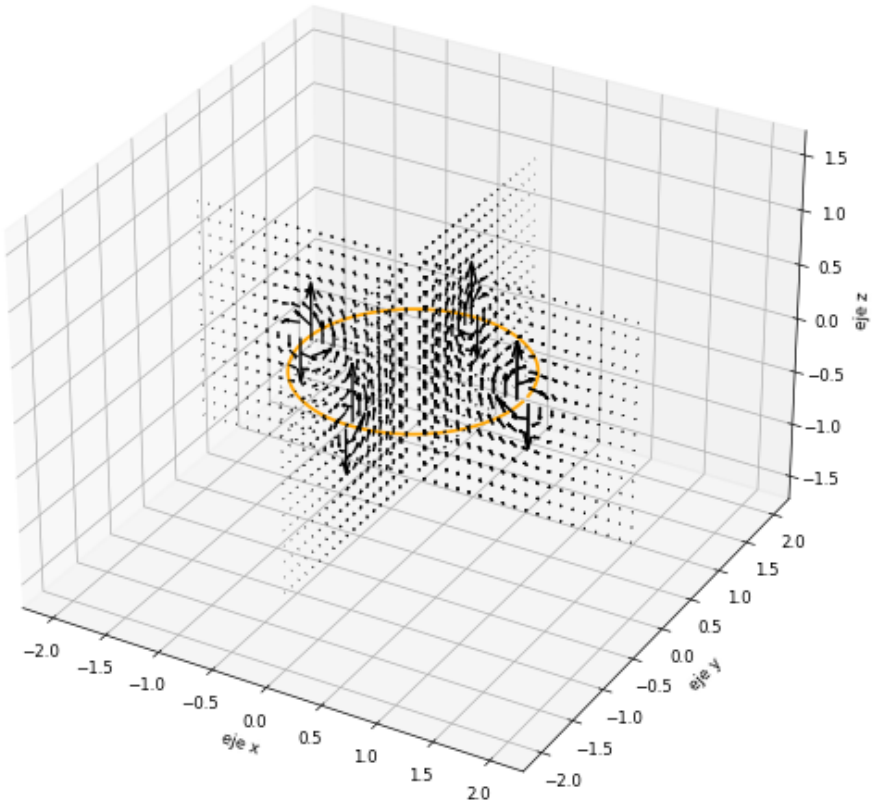
Out[509]:
$$-\frac{0.353553390593274\sqrt{2}a\sqrt{m}z\left(-\frac{E(2-m)}{2-2m}+K\right)}{(ar)^{1.5}}$$

In [510…
```
Bz1
```

Out[510]:
$$\frac{0.353553390593274\sqrt{2}a\sqrt{m}\left(\frac{Eam}{2-2m}+r\left(-\frac{E(2-m)}{2-2m}+K\right)\right)}{(ar)^{1.5}}$$

In [511…
```
Bx=sp.lambdify([a,r,phi,z,K,E,m],Bxyz[0])
By=sp.lambdify([a,r,phi,z,K,E,m],Bxyz[1])
Bz=sp.lambdify([a,r,phi,z,K,E,m],Bxyz[2])
```

In [562…
```
aa=1
fig = plt.figure(figsize=(10,10))
ax = plt.axes(projection='3d')

#rr=np.linspace(aa-0.5,1.5*aa,10)
rr=np.linspace(0,2*aa,20)
pp=np.linspace(0,2*np.pi,5)
zz=np.linspace(-1,1,15)
R,P,Z=np.meshgrid(rr,pp,zz)

X=R*np.cos(P)
Y=R*np.sin(P)


mm=4*aa/(Z**2/R+2*aa+R+aa**2/R)#(4*aa*R)/(Z**2+(aa+R)**2)
#mm=4*aa*R/(Z**2+aa**2)
Bxx=Bx(aa,R,P,Z,KK(mm),EE(mm),mm)
Byy=By(aa,R,P,Z,KK(mm),EE(mm),mm)
Bzz=Bz(aa,R,P,Z,KK(mm),EE(mm),mm)

ppp=np.linspace(0.1,2*np.pi,100)
BB=np.sqrt(Bxx**2+Byy**2+Bzz**2)
ax.plot(aa*np.cos(ppp),aa*np.sin(ppp),ppp*0,color='orange',lw=2)
plt.xlabel('eje x')
plt.ylabel('eje y')
ax.set_zlabel('eje z')
ax.quiver(X,Y,Z,Bxx,Byy,Bzz,color='black',length=1/40)
#ax.quiver(X,Y,Z,Bxx/BB,Byy/BB,Bzz/BB,color='black',length=1/5)

plt.axis('equal')
```

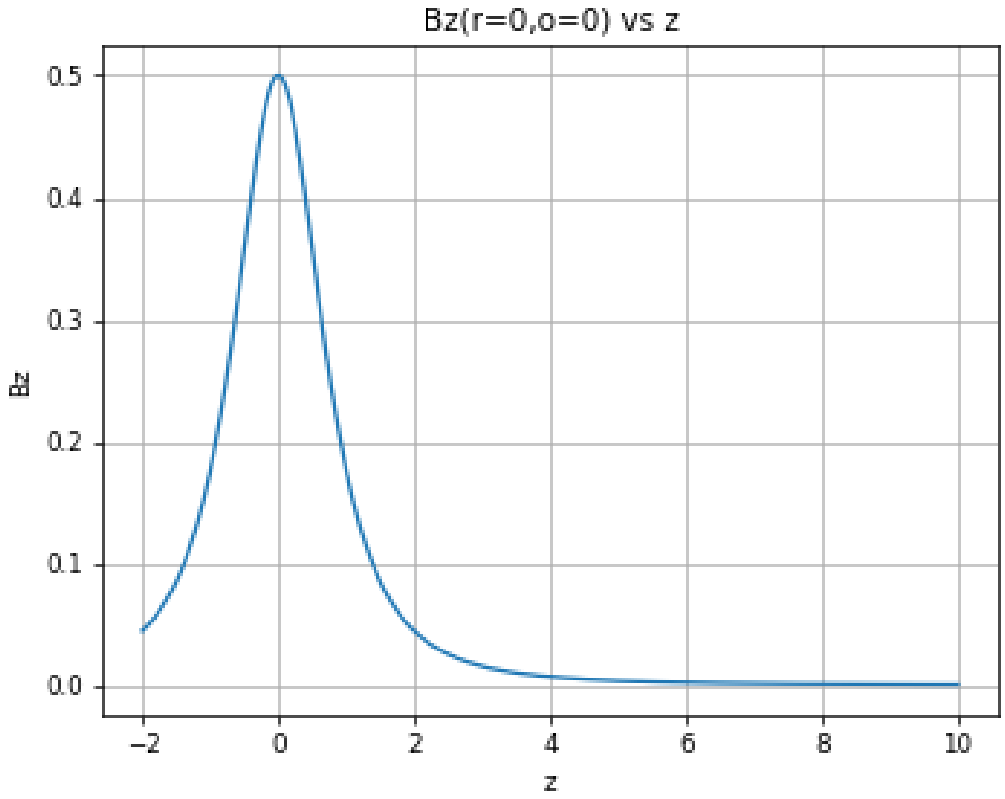



```
C:\Users\Arif\AppData\Local\Temp\ipykernel_10280\868724191.py:15: RuntimeWarning:
divide by zero encountered in divide
  mm=4*aa/(Z**2/R+2*aa+R+aa**2/R)#(4*aa*R)/(Z**2+(aa+R)**2)
C:\Users\Arif\AppData\Local\Temp\ipykernel_10280\868724191.py:15: RuntimeWarning:
invalid value encountered in divide
  mm=4*aa/(Z**2/R+2*aa+R+aa**2/R)#(4*aa*R)/(Z**2+(aa+R)**2)
```

Out[562]: (-2.2, 2.2, -2.2, 2.2)

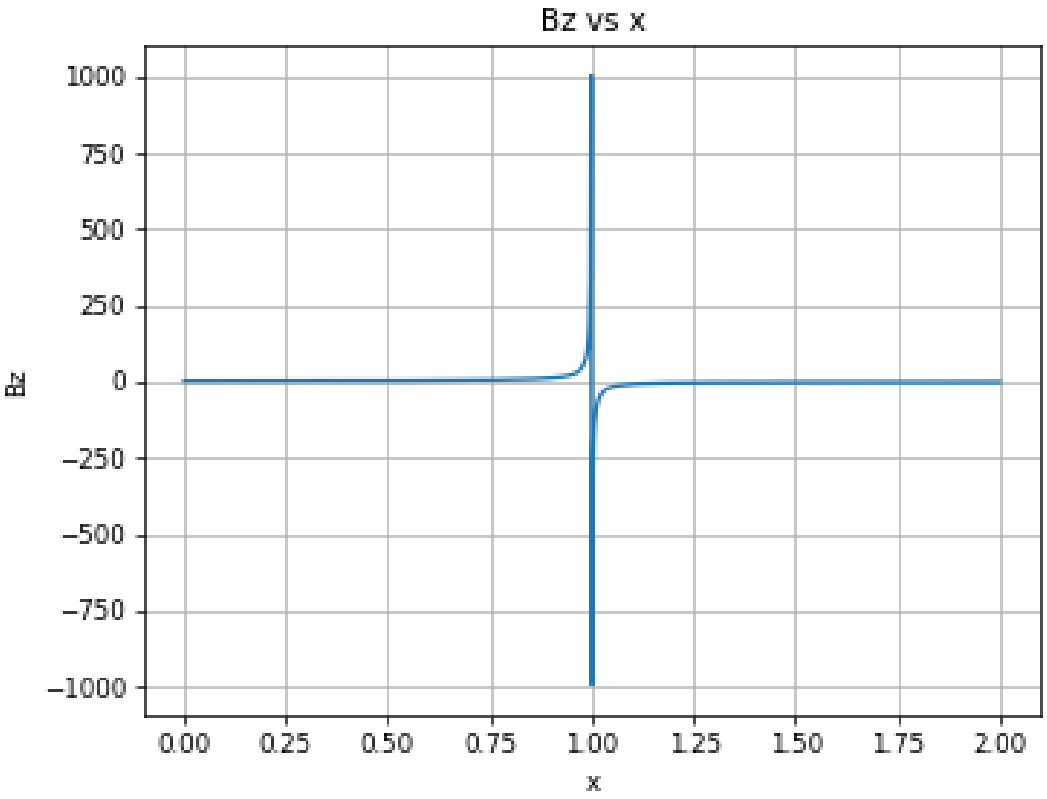
In [563…

```
zz=np.linspace(-2,10,10000)
mm=4*aa*0/(zz**2+aa**2)
fig5=plt.figure()
BZ=aa**2/(2*(zz**2+aa**2)**(3/2))
plt.title('Bz(r=0,o=0) vs z')
plt.xlabel('z')
plt.ylabel('Bz')

plt.plot(zz,BZ)
plt.grid('on')
```



In [565…

```
fig=plt.figure()
rr=np.linspace(0,2*aa,1000)
mm=4*aa/(2*aa+rr+aa**2/rr)
BZZ=Bz(aa,rr,0*rr,rr*0,KK(mm),EE(mm),mm)
plt.title('Bz vs x')
plt.plot(rr,BZZ)
plt.xlabel('x')
plt.ylabel('Bz')
plt.grid('on')
```



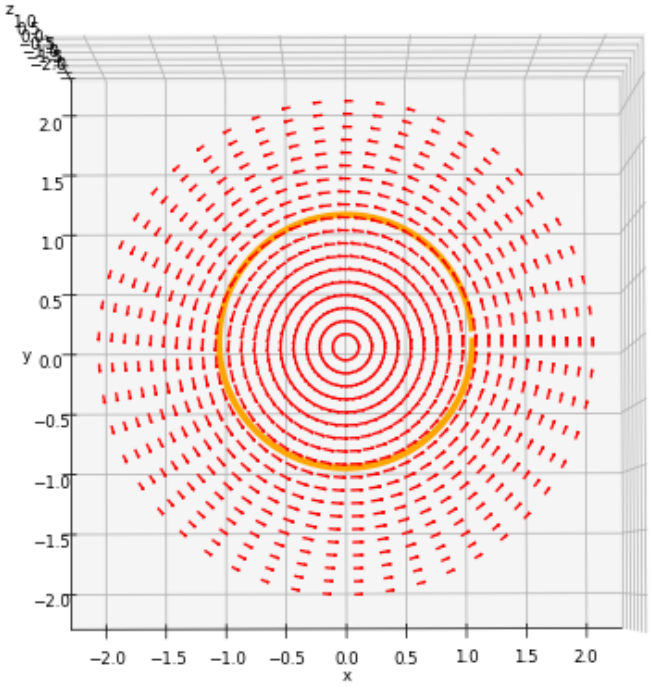

```
C:\Users\Arif\AppData\Local\Temp\ipykernel_10280\2889046768.py:3: RuntimeWarning:
divide by zero encountered in divide
  mm=4*aa/(2*aa+rr+aa**2/rr)
```

Potencial electrico A

In [560…

```
#Ao=(a/sp.sqrt(2*a*r))*(4*E/sp.sqrt(2*m)-(2-m)*sp.sqrt(2*m)*K/m)
Ao=-sp.sqrt(a/r)*((4*E/(2*sp.sqrt(m)))-((2-m)*K*sp.sqrt(m)/m))
#Ao=(a/((2*a*r)**(3/2)))*(K*sp.sqrt(2/m)-2*E*sp.sqrt(2*m)/(4*m**2))
A=sp.Matrix([0,Ao,0])
Axyz=Cart*A
Ax=sp.lambdify([a,r,phi,z,K,E,m],Axyz[0])
Ay=sp.lambdify([a,r,phi,z,K,E,m],Axyz[1])
Az=sp.lambdify([a,r,phi,z,K,E,m],Axyz[2])
fig7 = plt.figure(figsize=(10,10))
bx = plt.axes(projection='3d')



mm=4*aa/(Z**2/R+2*aa+R+aa**2/R)#(4*aa*R)/(Z**2+(aa+R)**2)
#mm=4*aa*R/(Z**2+aa**2)
Axx=Ax(aa,R,P,Z,KK(mm),EE(mm),mm)
Ayy=Ay(aa,R,P,Z,KK(mm),EE(mm),mm)
Azz=Az(aa,R,P,Z,KK(mm),EE(mm),mm)

ppp=np.linspace(0.1,2*np.pi,100)
AA=np.sqrt(Axx**2+Ayy**2+Azz**2)
bx.plot(aa*np.cos(ppp),aa*np.sin(ppp),ppp*0,color='orange',lw=4)
```

```
#bx.quiver(X,Y,Z,Axx/AA,Ayy/AA,Azz/AA,color='red',length=1/5,label='Potencial A')
#bx.quiver(X,Y,Z,Bxx/BB,Byy/BB,Bzz/BB,color='black',length=1/10,label='Campo magnet
#bx.quiver(X,Y,Z,Axx,Ayy,Azz,color='red',length=1/7,label='Potencial A')

bx.quiver(X[:,:,0].reshape(-1),Y[:,:,0].reshape(-1),Z[:,:,0].reshape(-1),Axx[:,:,0]
plt.legend()
plt.axis('equal')
plt.xlabel('x')
plt.ylabel('y')
bx.set_zlabel('z')
```



```
C:\Users\Arif\AppData\Local\Temp\ipykernel_10280\3183091739.py:14: RuntimeWarning:
divide by zero encountered in divide
  mm=4*aa/(Z**2/R+2*aa+R+aa**2/R)#(4*aa*R)/(Z**2+(aa+R)**2)
C:\Users\Arif\AppData\Local\Temp\ipykernel_10280\3183091739.py:14: RuntimeWarning:
invalid value encountered in divide
  mm=4*aa/(Z**2/R+2*aa+R+aa**2/R)#(4*aa*R)/(Z**2+(aa+R)**2)
<lambdifygenerated-304>:2: RuntimeWarning: divide by zero encountered in divide
  return sqrt(a/r)*(2*E/sqrt(m) - K*(2 - m)/sqrt(m))*sin(phi)
<lambdifygenerated-304>:2: RuntimeWarning: invalid value encountered in subtract
  return sqrt(a/r)*(2*E/sqrt(m) - K*(2 - m)/sqrt(m))*sin(phi)
<lambdifygenerated-305>:2: RuntimeWarning: divide by zero encountered in divide
  return -sqrt(a/r)*(2*E/sqrt(m) - K*(2 - m)/sqrt(m))*cos(phi)
<lambdifygenerated-305>:2: RuntimeWarning: invalid value encountered in subtract
  return -sqrt(a/r)*(2*E/sqrt(m) - K*(2 - m)/sqrt(m))*cos(phi)
No artists with labels found to put in legend.  Note that artists whose label star
t with an underscore are ignored when legend() is called with no argument.
```

Out[560]: Text(0.5, 0, 'z')

In [520…
```
m1=4*a*r/(z**2+(a+r)**2)
m1
```

Out[520]:
$$\frac{4ar}{z^2 + (a+r)^2}$$

In [521…
```
Ao
```

Out[521]:
$$\sqrt{\frac{a}{r}}\left(\frac{2E}{\sqrt{m}} - \frac{K\,(2-m)}{\sqrt{m}}\right)$$

In [522…
```
#CA=sp.simplify(sp.Matrix([-(1/r)*sp.diff(r*A[1],z),0,(1/r)*sp.diff(r*A[1],r)]))
```

derivadas de K y E

In [523…
```
dKdm=(1/2)*((E/(m*(1-m))-K/m))
dEdm=(1/2)*((E-K)/m)
```

In [532…
```
CA=sp.simplify(sp.Matrix([-(sp.diff(A[1],z)+sp.diff(A[1],K)*dKdm*sp.diff(m1,z)+sp.d
                          0,
                          (1/r)*(sp.diff(A[1]*r,r)+sp.diff(A[1]*r,K)*dKdm*sp.diff(m
```

In [533…
```
sp.simplify(CA)
```

Out[533]:

$$\begin{bmatrix} \dfrac{arz\sqrt{\frac{a}{r}}(-8.0(E-K)(m-1)+4.0(E+K(m-1))(m-2)+4(m-1)(2E-2Km+K(m-2)))}{m^{\frac{3}{2}}(m-1)\left(z^2+(a+r)^2\right)^2} \\ 0 \\ \dfrac{\sqrt{\frac{a}{r}}\left(-8.0ar(E-K)(m-1)\left(-2r(a+r)+z^2+(a+r)^2\right)+4.0ar(E+K(m-1))(m-2)\left(-2r(a+r)+z^2+(a+r)^2\right)\right.}{\left.+4ar(m-1)(2E-2Km+K(m-2))\left(-2r(a+r)+z^2+(a+r)^2\right)-m(2E+K(m-2))(m-1)\left(z^2+(a+r)^2\right)^2\right)} \\ \hline 2m^{\frac{3}{2}}r(m-1)\left(z^2+(a+r)^2\right)^2 \end{bmatrix}$$

In [534…

```
mmm=4*1/(1+(1+1)**2)
K3=KK(mmm)
E3=EE(mmm)
Dif=(B.subs(m,m1)-CA).subs(m,m1).subs(r,1).subs(a,1).subs(z,1).subs(K,K3).subs(E,E3
float(Dif[0])
```

Out[534]:

```
-3.389148532322937e-16
```

In [535…

```
float(Dif[2])
```

Out[535]:

```
8.90933473612742e-18
```

In [ ]: